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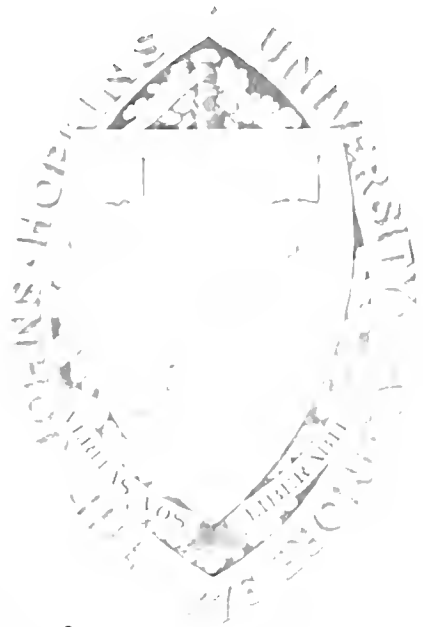

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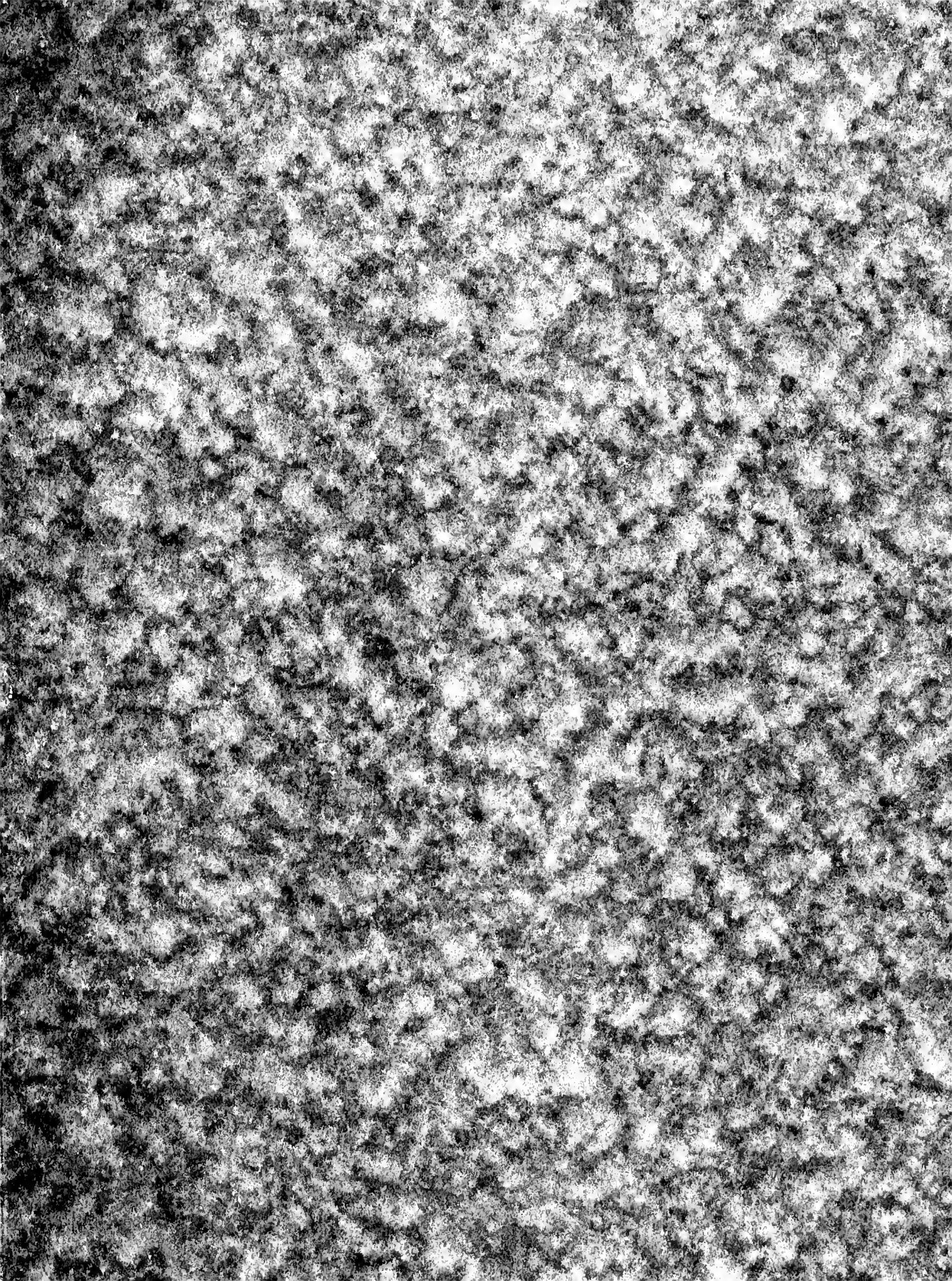

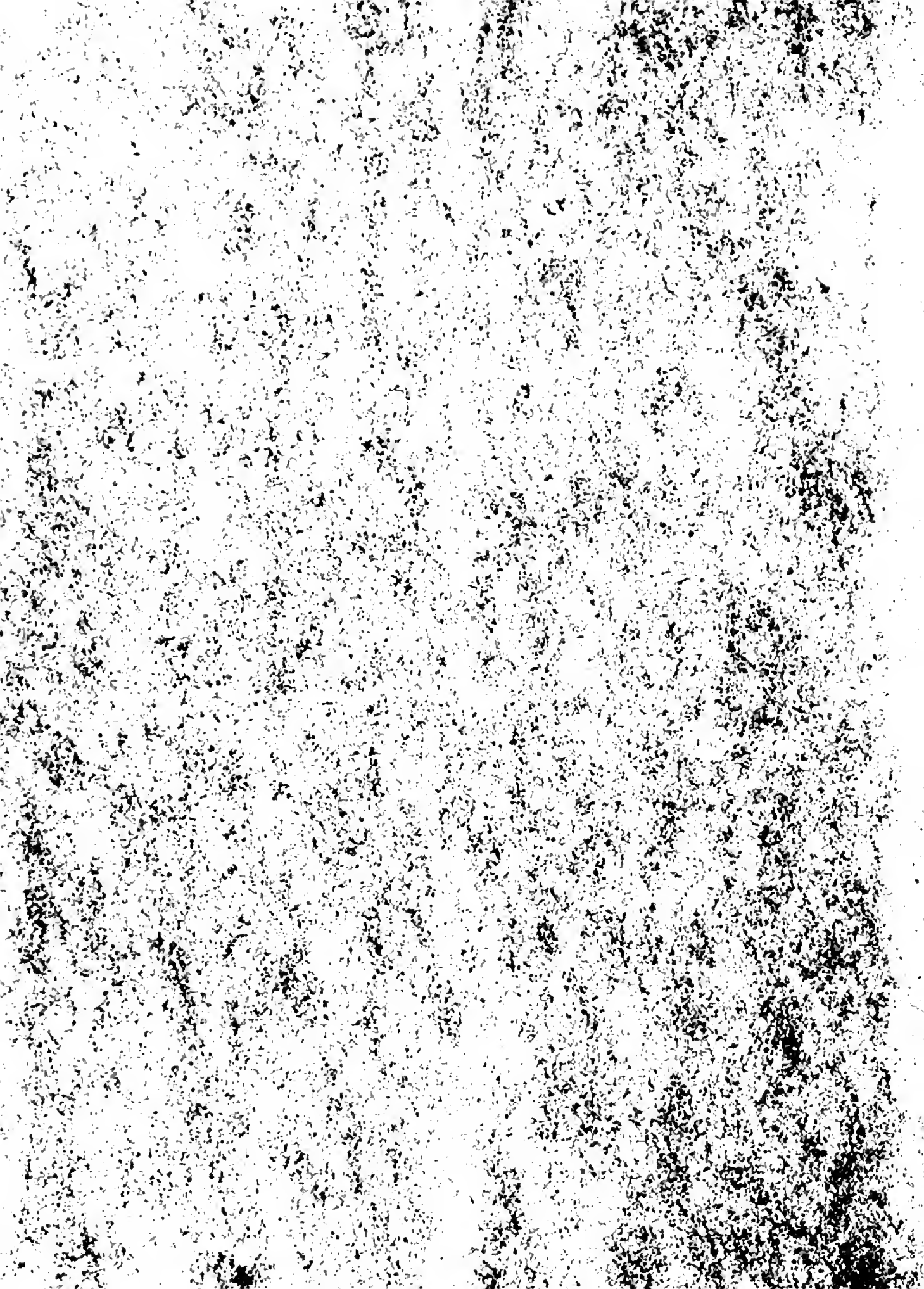

[illegible]

By

Carl [illegible] Berget

A DISSERTATION

Submitted to the Board of University Studies

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for the Degree of

Doctor of Philosophy

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Introduction

The present work was undertaken for the purpose of making ultrasonic measurements near the critical point. The main emphasis in the work of this thesis is to the presentation of exact information available in this important region. More precise information not only of the critical state itself, but of the region about it is especially desirable for its bearing upon the equation of state, for the better understanding of the forces between molecules, and for any light that may be shed upon the nature of the liquid state. It is thus seen that the program attempted is larger than the collection of data for use in evaluating the ratio of specific heats, a use to which studies of sonic velocities have largely been limited in the past. The results presented here are encouraging beyond anticipation and the study was undertaken.

That the sonic method of investigating thermodynamic problems would appeal to most chemists has long been realized; however, the very great theoretical accuracy of the method has only recently been detailed. This is due to the fact that older measurements employed audible sound, of wavelengths of many dimensions, thereby necessitating corrections too large for the effect of the fluid upon the sound propagation. The corrections were of uncertain accuracy at best. With the development of ultrasonic technique, it became possible for the first time to use wavelengths small in comparison to the dimensions of the apparatus and thus easily eliminate the necessity for wall corrections. Although it has been theoretically diffraction corrected by

having a source of sound large compared to the wavelength. The elimination of these troublesome effects with the corresponding freedom from the necessity of applying corrections of uncertain validity, in either the resonance method, or the use of ultrasonic techniques, is the chief source of its superiority.

For a gas in the critical region, all the above advantages become enormously magnified. In addition, the ultrasonic velocity measurement in the critical region is one of the only difficulties encountered in other methods of studying the critical state, namely, the extremely large effect on small amounts of impurities. Investigations, for example, of the difference in density between the two phases in the critical solution of two gases are influenced by the presence of small traces of impurities out of proportion to the total amount of impurity present because of the tendency of the foreign substance to concentrate in the liquid phase. The compressions and rarefactions of an ultrasonic wave in following each other so rapidly that there is not much chance for the impurity to redistribute itself between them, and its effect is therefore more in proportion to its abundance.

It is, too, since in general the velocity of sound is given by

$$c^2 = \left(\frac{\partial P}{\partial \rho}\right)_s$$

measurement of the velocity of sound gives directly the value of a derivative rather than a quantity whose derivative must be estimated.

It follows, then, that for equal accuracy in determining α, higher derivatives must become increasingly significant in determining for the case of ultrasonic velocity measurements.

Indeed, the digital computer and ultrasonic measurements have virtually outstripped the theorist temporarily, so that the burden is on theory to catch up with the practical demands of the fluid industry and the nation.

Apparatus

Two pressure acoustic interferometers were used. One was an instrument of the moveable piston type, used previously by A. M. Hodge. It will not be necessary here to recount a description of this instrument, since it may be found elsewhere (2), (4).

The second pressure interferometer, shown in Figure 1, was of the constant path type. It was formed from a solid block of hot rolled steel. The top was held on the chamber by eight 7/8" bolts A.S.I. The thread leak-tight sealing between the chamber and top was accomplished by the standard method of pressing copper gaskets under a V shaped circular projection from the top. When the nuts were fully tight, the copper under the projection flowed enough to seal the gasket against itself. The pressure unit was designed to be safe at 700 atmospheres and temperatures ranging from -50°C to 150°C, and could probably have been taken up to 1000 atmospheres without any danger save for an unfortunate circumstance. This misfortune was discovered upon testing the chamber at 700 kg. per square inch with hydrostatic pressure: water leaked through the

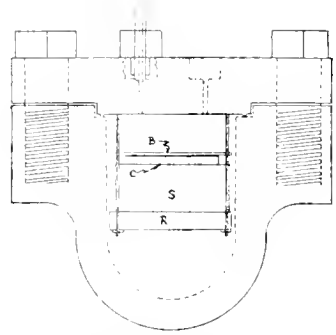
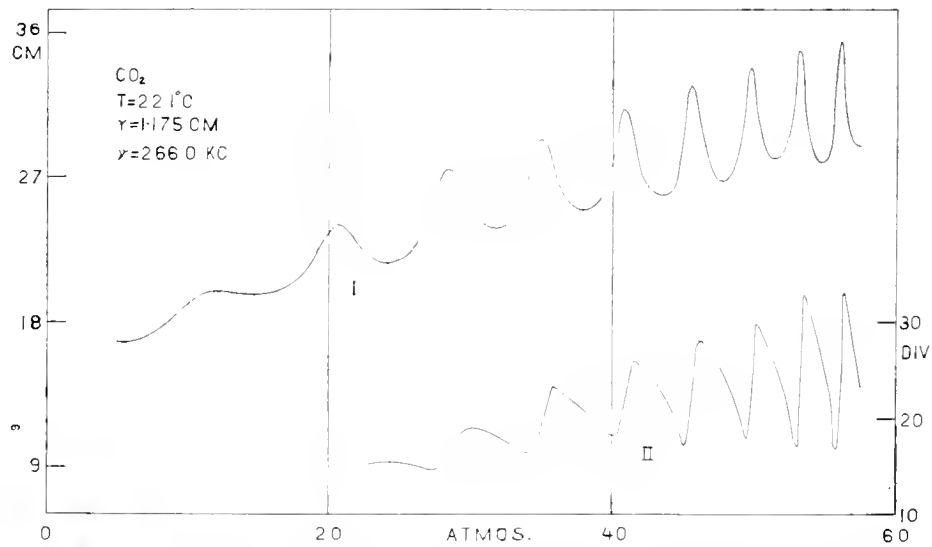


FIG. 1. The constant path acoustic interferometer in place within the pressure chamber. *B*- Backing; *C*- quartz crystal; *S*- separator; *R*- reflector.

Fig. 1



[redacted]. Peak structure in CO_2 as a function of pressure. Curve I, galvanometer current *vs.* pressure. Curve II, Vernier condenser readings (arbitrary scale) *vs.* pressure to show change of phase while passing through resonance points.

Fig. 1 a

[redacted] of the curve [redacted] in relation to the [redacted] interferometer.

[illegible] Chart 2 [illegible] shifting knobs. [illegible] left [illegible] were in the top, [illegible] to [illegible] pressure drop about 7 pounds per hour. Later on [illegible] interlock if the door could [illegible] during [illegible] up to 700 pounds per hour, when [illegible] water [illegible] portion of the [illegible], it was concluded that [illegible] present originally in the block from which the [illegible] been cut. The most probable [illegible] to [illegible] very [illegible] of the [illegible] of the [illegible] out during the [illegible] polishing [illegible] were cut [illegible] the [illegible] out. Notwithstanding this [illegible] effort, it was decided safe to [illegible] the charge for low pressure, and it was [illegible] up to [illegible] pressure [illegible] out by [illegible] or spare [illegible].

The interferometer [illegible] proper was [illegible] fitted parts. The reflector [illegible] a circular [illegible] of fused quartz 1 3/4" [illegible] 1" meter and 1/4" [illegible]. The separators were [illegible] interchangeable sets [illegible] of fused quartz, 1" outside [illegible] and 7/8" inside [illegible], but differed [illegible] proper. The smaller one is 0.2497" [illegible] high; the [illegible]'s height is 0.999" (exactly [illegible] the [illegible]). 1/4" [illegible] cut in the separators [illegible] two extra [illegible] diameter, and 1/8" [illegible] into the reflector allowed [illegible] to be used [illegible] quartz [illegible]. The [illegible] were threaded [illegible] ends; the upper [illegible] used to secure threaded [illegible] in the top of the [illegible], [illegible] cut on the lower end of each was sufficient to [illegible] the quartz parts. The [illegible] was held on the reflector [illegible] free floating [illegible], so that no expansion or [illegible] of the [illegible] could change the relative [illegible] of the two [illegible].

The upper surface of the crystal was [illegible] the height of a thin film of gold, [illegible] that both faces of the crystal were silvered. [illegible] face was electrically and optically in [illegible] surface in contact with the crystal [illegible]. Good [illegible] contact could thus be made to the face of the crystal. In practice, the bottom face was [illegible] grounded to the [illegible] potential was applied to the upper face by means of the gold plate of the optic lever flat backing. This backing served another purpose, besides that of making this contact: since it rested on the crystal, it was adjusted to it that an acoustic quarter wave length. Therefore, any reflection from the back of the crystal was allowed to form standing waves and give thereby acoustic reactions which would be confused with the desired ones formed between crystal and reflector.

Two 1/16" holes in the top of the chamber served as gas inlet and outlets; two more allowed thin tungsten wires to be led in to make electrical contact with the crystal. These wires had to be insulated from the chamber, which insulation was accomplished by enclosing them in a thin sheath of pyrex glass. The electrode was made leak-proof by leading the wire through a rubber cone which fitted into a female conical depression in the brass plug. When the top was screwed over the top of the electrode, this cone was forced tightly against the walls, and collapsed against the wire, so that no gas could leak out.

[illegible] the [illegible] drive [illegible] was [illegible] terminated in a 1/4" [illegible] dia through wire [illegible] 1/16" [illegible]. On right hand [illegible] forcing [illegible] the end of the rod [illegible] force come in the top of the [illegible] by the force of a [illegible] the diameter of the [illegible]. This rod [illegible], of course, the standard metal rod.

The procedure was [illegible] Ashcroft-American gage [illegible] previously been [illegible] the manual of Standard and found accurate to within .5 percent over the entire range (1). The gage was placed in the line between the gas tank and the transformer, and a [illegible] was so arranged that the line could be closed, providing the gage open to the [illegible] closed to the gas [illegible].

A standard method was used to drive the quartz rod. It was placed in parallel with the condenser of a resonant circuit which [illegible] oscillations from an electron coupled oscillator. The current in the resonant circuit was measured by inserting a vacuum thermocouple and reading the [illegible] across it by (L and N) galvanometer. The frequency of the oscillator was checked by using as standard the carrier waves of local broadcast stations. These stations are required by law to maintain within 50 cycles of their assigned frequency and to afford a variation frequency standard sufficient accuracy. The [illegible] was [illegible] on a tuned circuit by receiving set and beat against the fundamental or overtones of the oscillator. The beat notes were then matched by ear. Beat with a standard signal by

[illegible] tuning fork. The [illegible] tones were set [illegible], one for an oscillator frequency higher than the station carrier wave by an amount equal to the frequency of the fork, the other for a frequency lower than the carrier wave by the same amount. The beating of the oscillator between these two tones was then the beating which would give exact correspondence (zero beat) between oscillator and station. Here, the frequency of the oscillator dial setting was taken roughly by means of a wavemeter. This allowed one to decide which one of the oscillator dial settings gave the beat, and the frequency of the setting could then be determined with an accuracy far surpassing the accuracy of other measurements (e.g., of pressure) which entered into the readings.

The interferometer during use was kept at a constant temperature in a thermostat filled with transformer oil. This was an iron tank 24" x 15" and 12" deep with a drain pipe in the bottom to facilitate the removal of oil when that was desirable. It was surrounded on all sides except the top by a two-inch layer of glass wool. A metal stirring paddle kept the oil in the bath well stirred, so that at the temperatures used there was nowhere detectable in the bath a difference greater than $\pm$ .01°C from the temperature at the interferometer. Heat was supplied by seven electric light bulbs dipping into the oil. Copper coils allowed the circulation of cool water from the tap; or by means of a small centrifuging pump, ice water could be forced through the coils. The temperature was automatically

[illegible] a control point [illegible] end of a mercury thermal regulator which operates relay to turn off or on the heating coils. Temperature regulation was also accomplished by circulating the water from the bath against the cooling which is either the circulation of tap water, or [illegible] radiation losses in the room when the bath was above room temperature. A 50° thermometer graduated in .1° which allowed estimations to .01° was used to determine the temperatures. This thermometer was checked at 25°C against a thermometer calibrated by the Bureau of Standards and was found to read less than .05° too high. In what follows, this correction has been disregarded.

Temperature readings were taken frequently, and if for any reason the bath temperature was off by more than ± .05° the condition was corrected and sufficient time allowed for the establishment of thermal equilibrium. Of course, the importance of strict temperature control varies with the region in which the gas may exist: at the critical point temperature control was of great importance, and every effort was made to keep conditions as constant as possible. Temperature readings were taken always with the thermometer in contact with the interferometer.

The carbon dioxide was obtained from a commercial "sweetened" tank, reportedly 99.5 percent pure. No attempt was made to purify the gas further, except that the valve was opened for a few minutes to allow some of gas to blow off into the atmosphere. The gas then [illegible]

[illegible] a [illegible] through a trap [illegible] ("magnesium perchlorate trap"). The carbon dioxide was found to contain slightly less than three parts per million by vapor.

The ethylene was of the so-called "anesthesia" grade, at least 99.5 percent pure and probably 99.7 percent pure, since at the time that the cylinder was bought, the impurity of the gas was higher than the lowest tolerance. Impurities would be chiefly carbon dioxide or water vapor, and it was thought that the latter of these in the following way: The cylinder was surrounded with crushed ice and salt, and allowed to cool for several hours. The valve was then opened and the gas allowed to bubble off until a pound or so of pressure had been spent. The valve was then closed and the remainder of the gas used. [illegible]

Since the pressure developed by the tank at low temperatures was usually below that desired, recourse was had to the following method to obtain higher pressures: The bath was cooled some ten degrees or more below room temperature and the reactor chamber and gas cylinder opened to each other. This caused the gas to enter the latter rapidly and completely. After a sufficient time, indicated by a pressure gage, the interconnection was closed off from the rest of the system by the needle valve at the gage, and the bath temperature raised. In this manner, pressures up to four pounds per square inch (the limit of the gage) could easily be reached.

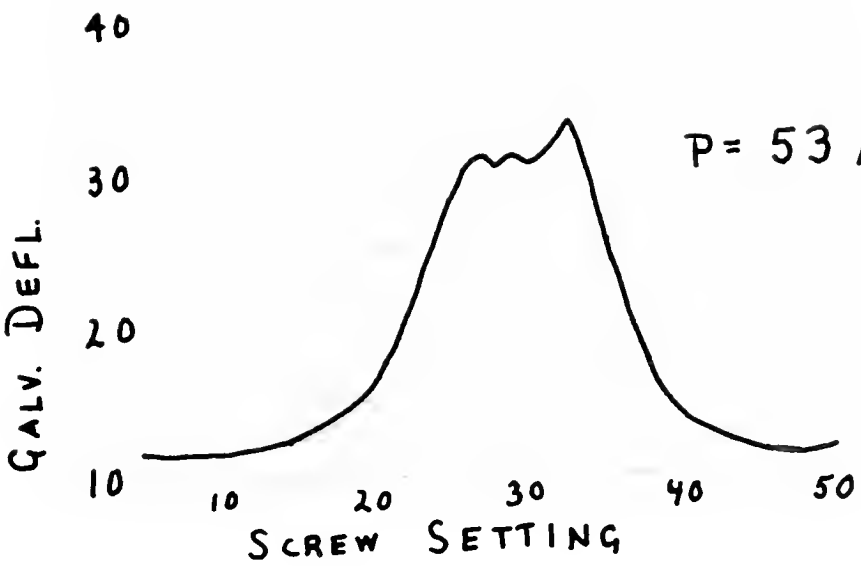


Fig. 2

Appearance [illegible] fracture [illegible] Thin [illegible] lower [illegible]

The theory of the piezoelectric interferometer was developed by Pierret still by Hubbard (3), so that it will be unnecessary here to give more than a brief statement of what occurs in the instrument: When an alternating potential is applied across the faces of the quartz crystal, the crystal undergoes distortion with a frequency equal to that of the applied electric field. The crystal, upon undergoing this distortion, creates (by the converse piezoelectric effect) charges on its faces opposite to those causing the distortion, so that the vibrating crystal may be regarded as a source of back electromotive force. The magnitude of the back emf. depends on the amplitude of the vibration, which is usually very small. However, if the frequency of the driving oscillator coincides with a natural frequency in the quartz crystal, the amplitude increases to comparatively high values and the back electromotive force increases greatly. The current in the driving circuit drops to a low value, which drop is known as a crevasse. The depth of this crevasse changes with the amplitude of the crystal changes; the greater the damping of the crystal, the higher is the crevasse. (Analogous statements are, that the back emf. is smaller; or, that the current in the resonant driving circuit has a higher value).

Consider now a fluid column coupled to the crystal and terminated by a solid reflecting wall. If the distance between the crystal and reflector be an integral number of half wavelengths, standing waves will be formed by the sound emitted from the source and that reflected from the reflector. This condition corresponds

[illegible] maximum of transfer of energy from the crystal to the fluid and given maximum damping of the crystal, one for the bottom of the crevasse if either that or both be more than the distance favorable for standing waves.

If the reflector be moved backward or forward this condition of resonance [illegible] and the crevasse bottom will fall out of the reflector or other distinct distance from the crystal corresponding to $\left(\frac{n \pm 1}{2}\right)\lambda$, but the crevasse bottom will rise again. The current in the resonant circuit will thus in some simple way be a function of position of the reflector corresponding to half wavelength oscillation. By measuring the distance through which the reflector is moved, the wavelength is determined, and if the frequency is also known, the velocity can be calculated. This is the basis for the interferometer (movable reflector) type of [illegible] measurement.

The problem of the constant path interferometer may be described as follows:

After standing waves have been set up in the fluid column by the source and reflector, suppose that the wavelength of sound in the fluid be altered, as by changing the pressure. It is clear that as the pressure change progresses, the standing wave system will become disappear, and likewise the resonant circuit current will drop. Continued change in pressure evidently [illegible] the wavelength to such a value that the bottom of one loop will move into

[illegible] reflector. [illegible] the [illegible] circuit current [illegible]; at [illegible] the [illegible] complex [illegible]. [illegible] which [illegible] occur, [illegible] velocity of [illegible] [illegible] [illegible] from [illegible] of the [illegible], which may [illegible] the number of half waves fitting into the source to reflector distance is [illegible].

To determine the number of half waves, it is necessary to know the velocity of [illegible] the [illegible] from [illegible] dust [illegible], which allows [illegible] of the number of dust points. The number of any other [illegible] can be arrived at by counting the number of reaction [illegible] from the known "reference" [illegible] to the [illegible] at which it is [illegible] to determine velocity, since each [illegible] is due to the [illegible] of [illegible] half wave. It should be noted, [illegible] the reference velocity serves only to [illegible] the number of half waves in the interference pattern, [illegible] the accuracy of the [illegible] obtained is not [illegible] by the accuracy with which the reference velocity is known, provided that this is not grossly in error. A simple example will make this clear: Suppose that at one reaction [illegible] maximum, calculation from the available data were to show 67.7 wavelengths distance. Even a number as [illegible] rule, for [illegible] maximum corresponds to an integral number of half waves. The true number would be considered [illegible], but a [illegible] correction, ascribed to error in the independent data, would be appropriate. By this procedure the error in the auxiliary data is automatically ruled out.

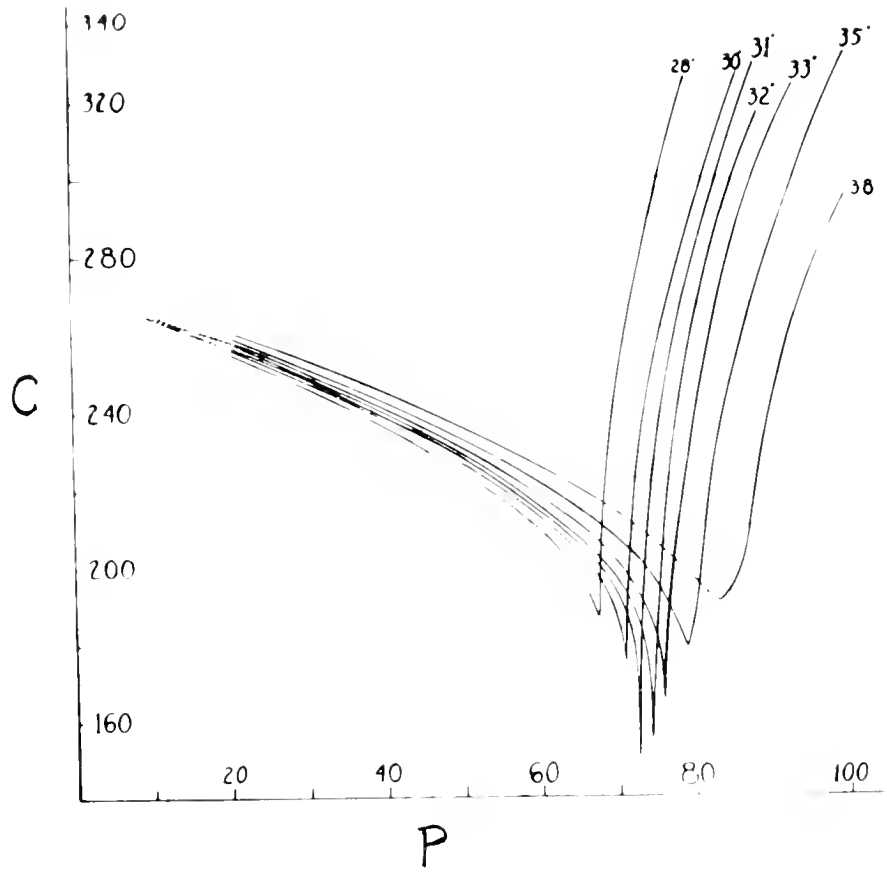


Fig. 3

Velocity of [illegible] dioxide [illegible] ure with temperature constant

[illegible] found [illegible] for [illegible] boundary layer [illegible] the [illegible]. The theory [illegible] is briefly [illegible]. Brailsford (4) shows that, for reflection [illegible] a plane boundary, a [illegible] may undergo a change of [illegible] of multiple [illegible] [illegible] large [illegible]. The results [illegible] effective [illegible] [illegible] of the acoustic interferometer which introduces a slight [illegible] in the velocity determination. It is possible to eliminate [illegible] using the different path lengths; however in the present work, the inaccuracy was so small as compared to other sources of error that it was disregarded.

Procedure

a) With the [illegible] interferometer

After the gas had been [illegible] to the desired [illegible] of the bath near the door of the [illegible], about an hour was allowed for thermal equilibrium to be established. Meanwhile, the oscillator was turned on, and an equal length of time allowed for it to stabilize itself. Several [illegible] during the run, either at the beginning or end, or both, a check was made on the frequency of the oscillator. The frequencies obtained from day to day all fell within an extreme of 500 cycles of one another and usually were [illegible] to [illegible] 200 cycles.

After everything was ready, the oscillator was set to a convenient [illegible] and the condenser in the [illegible] circuit was adjusted so as to make this crossover as sharp as possible. Fine adjustment

was sometimes futile, as will be explained later. The interferometer was first set up with the crystal, [illegible] by trial to treat wavelengths. Then the micrometer was sufficient to give wavelength values agreeing with each other to better than (one part in 300) in the best cases. At other times the measurements were good, due to matters to be discussed later. The procedure was then reduced to another definite point, the value sought for the re-establishment of equilibrium, by crevasse a judgment was made, and another set of observations taken.

c) With the constant path interferometer

The procedure was to set up the equilibrium established as before. The fringe crevasse was found, and its position made for symmetry. The gas was then allowed to leak out very slowly, with the simultaneous adjustment of the current through the variable condenser of the oscillator, the crevasse kept symmetrical and its motion followed. If the current in the resonant circuit (as followed on the galvanometer), of the receiver, and of the variable oscillator condenser. The value in the resonant circuit current indicated resonance at which the standing wave pattern was produced.

To determine whether the velocity was increasing or decreasing, a convenient method was the use of the notch: If the current is plotted against the crevasse, the spacing of the notches will show in which direction the velocity is changing: a closer spacing towards the galvanometer means that the velocity is decreasing (i.e. the number of peaks is increasing per pressure increment).

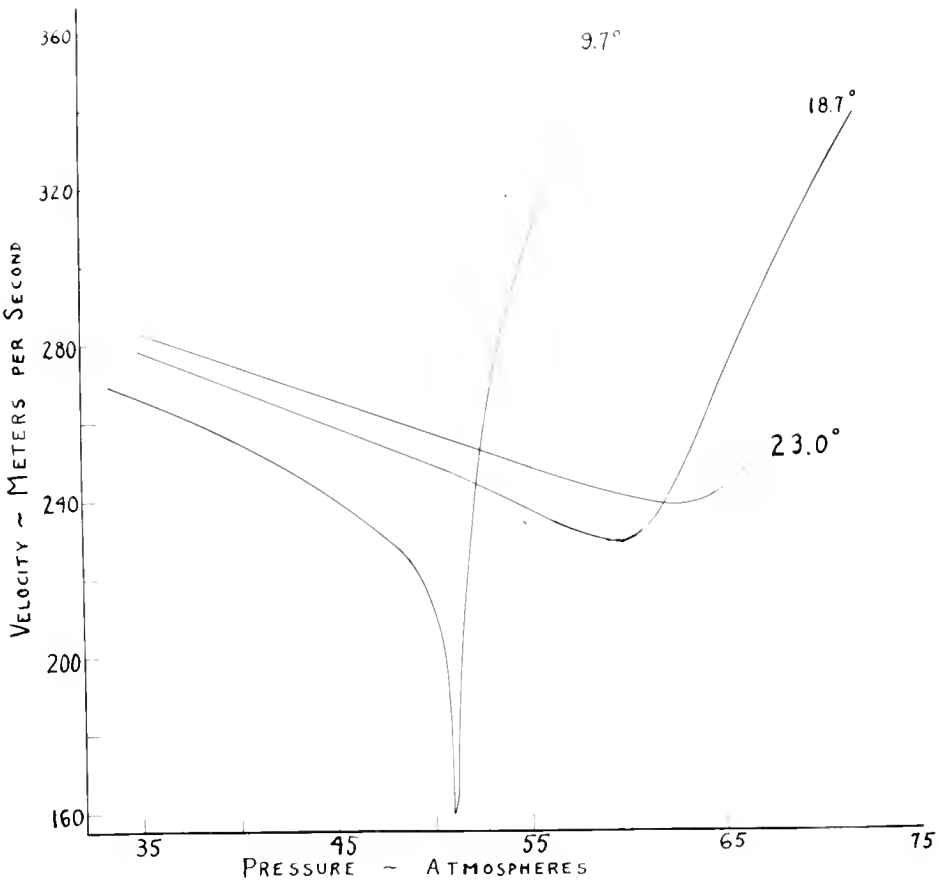


Fig. 4

Velocity ... in ele... ...ct on
... pr... ... of th... constant

[illegible] to [illegible] [illegible] of [illegible].

[illegible] figure [illegible] pressures [illegible] to 5 [illegible].

In the higher range of [illegible], the crevasse [illegible] completely, [illegible] liquid [illegible] ($1, 7$). [illegible] reflector [illegible]

$\left(\frac{\quad}{4}\right)$ [illegible] reflector [illegible] the [illegible] of the [illegible] reflection depends [illegible] of the fluid, [illegible] of the [illegible] crevasse. [illegible], although [illegible]. The velocities [illegible] of reflection, [illegible] for [illegible].

[illegible]

The velocity of sound in CO_2 [illegible] the field of [illegible] obtained. [illegible] the accompanying tables, [illegible] data.

As is well known, CO_2 [illegible] of sound velocity in a range of frequencies which [illegible]

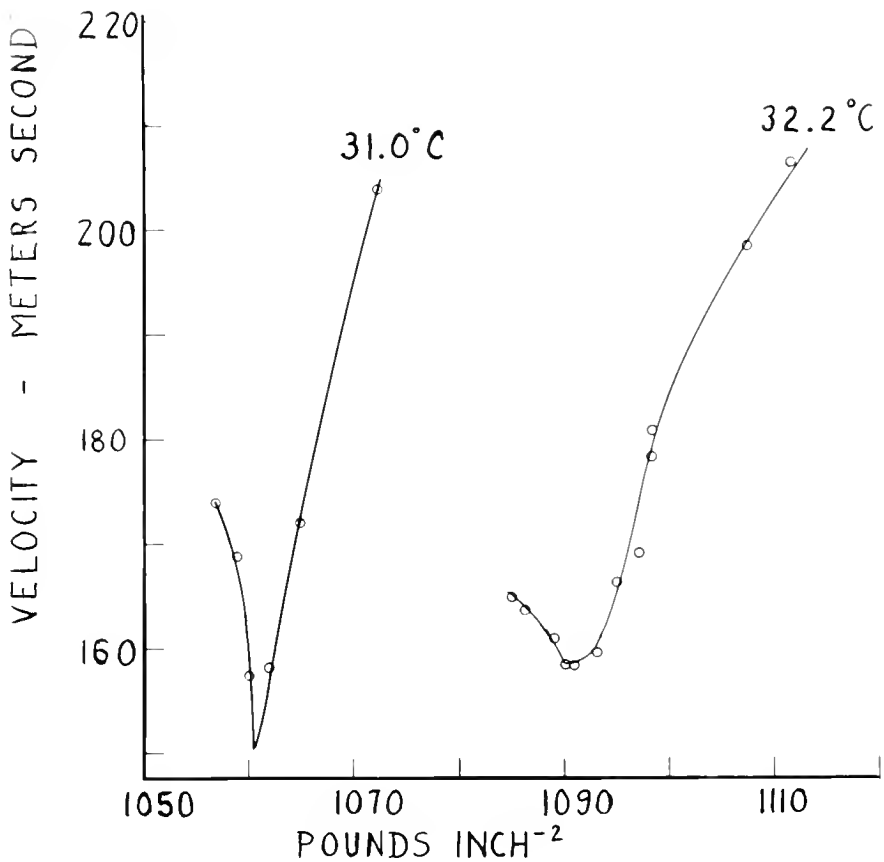


Fig. 5

Large scale plot of velocity of sound [illegible] with the cusp-like form of the minima

[illegible] these [illegible] region, [illegible], [illegible] velocity [illegible] CO_2 [illegible], [illegible] that [illegible] be omitted here, [illegible] that [illegible] the cause of [illegible], [illegible] ruled out.

Furthermore, [illegible] specific heat [illegible] from [illegible] velocity measurements [illegible] CO_2 at [illegible]°C and from the to [illegible] [illegible] definite [illegible] of [illegible] value [illegible].

[illegible] the general [illegible] velocity [illegible] are [illegible] to [illegible] more [illegible] curvature of the curve [illegible] minimum. On the condensed scale on which they are drawn, [illegible], [illegible] for [illegible] lower [illegible] very [illegible], there [illegible] continuity [illegible].

[illegible]° velocity-[illegible] first investigated. It must [illegible] remembered [illegible] the apparatus [illegible] too [illegible] close [illegible] from [illegible] to the [illegible] pres- [illegible] the [illegible]. [illegible] the [illegible]° curve [illegible] continued [illegible] through the minimum.

[illegible] continuity [illegible] temperature [illegible] above the critical [illegible] theory of [illegible] (5), the nature of the minimum at [illegible].2°C was in- vestigated. An attempt [illegible] first [illegible] to effect [illegible] in [illegible]. The gas was collected [illegible] from [illegible] cylinder; [illegible] 100 cc

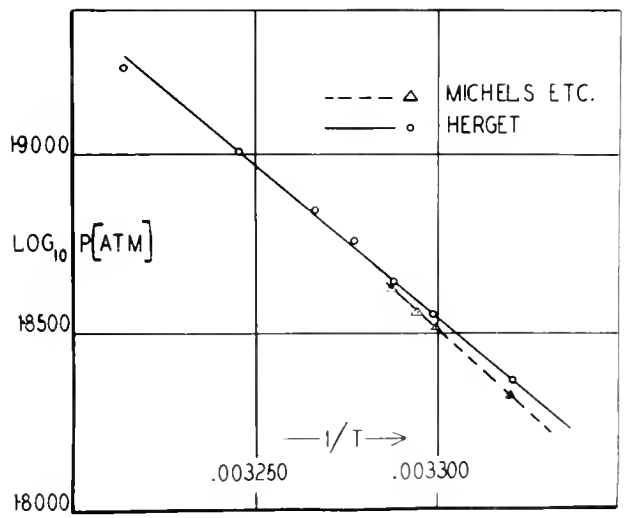


Fig. 6

Log of pressure (in atmospheres) vs. 1/T for the minima of the velocity of sound curves for carbon dioxide

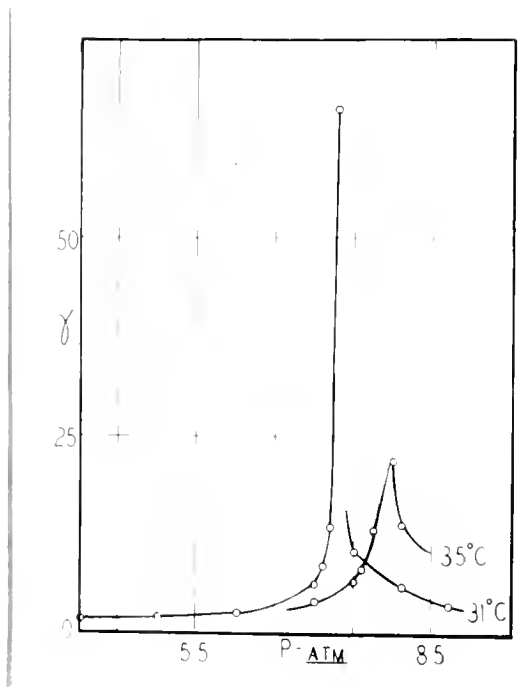


Fig. 7

[illegible] for carbon dioxide v. pressure for 31°C (critical temperature) and 35°C, as calculated from sound velocity data in conjunction with Amagat's pv data.

[illegible], [illegible], 8.0°C

Frequency	Velocity	Wavelength	Frequency	Energy	Wavelength
[illegible]	217.4	77.50	287.5	[illegible]	[illegible].27
[illegible]	214.7	77.17	277	18.9	15.0
266	202.3	75.45	266	[illegible]	67.34
257.5	204.4	71.31	257	[illegible]	[illegible].35
[illegible].5	[illegible]1.4	74.21	246	[illegible]	[illegible].71
237.5	228.6	73.61	236	49.3	63.11
227.5	[illegible]1.7	72.49	226	[illegible]	12.53
217	[illegible].8	71.8	216	[illegible]	51.79
[illegible]	211.9	[illegible].21	206	[illegible]	41.31
197.5	(211.7)	69.99	196	[illegible].4	37.40
187.5	18[illegible].[illegible]	69.65	186	21.0	[illegible].57
177	[illegible].9	69.7	176	[illegible].1	8.76

Carbon dioxide. Temperature, 30.0°C

[illegible]	2[illegible].8	85.[illegible]	156	[illegible].2	7[illegible].20
[illegible].5	3[illegible].9	81.[illegible]	216	25.5	[illegible].42
[illegible].5	[illegible].9	78.41	206	[illegible].4	70.50
91.5	[illegible]2.3	7[illegible].81	[illegible].5	[illegible].4	7[illegible].[illegible]
[illegible].5	[illegible].9	7[illegible].[illegible]	[illegible]1	[illegible].[illegible]	[illegible].81
17	[illegible]3[illegible].4	7[illegible].[illegible]	[illegible]0	13.[illegible]	7[illegible].18
8[illegible]	[illegible]87.2	7[illegible].[illegible]	[illegible]2	[illegible].4	63.22
[illegible].	[illegible].[illegible].7	7[illegible].[illegible]	166	[illegible].5	55.[illegible]
[illegible]	[illegible]86.4	7[illegible].[illegible]	[illegible]6	[illegible].5	[illegible].41
[illegible]	[illegible]87.0	7[illegible].[illegible]	[illegible]6	[illegible].7	[illegible].80
[illegible].[illegible]	[illegible]8[illegible].[illegible]	7[illegible].77	[illegible]6	[illegible].[illegible]	[illegible].7[illegible]
[illegible]	177.2	7[illegible].7[illegible]	[illegible]6	[illegible].2	[illegible].[illegible]
[illegible]	177.4	7[illegible].[illegible]	[illegible]6	[illegible].[illegible]	[illegible].79

[illegible] Temperature, 11.2°C

Frequency Kilocycles	Velocity meters/sec.	Reflection at [illegible]	Frequency K'loc [illegible]	Velocity meters/sec.	Reflection at Nare
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Carbon Dioxide. Temperature, 31.0°C

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Carbon dioxide. Temperature, 30.0°C

Frequency Kilocycles	Velocity Meters/sec.	Pressure Atmospheres	Frequency Kilocycles	Velocity cm./sec.	Pressure Atmospheres
[illegible]	323.[illegible]	[illegible].85	[illegible]	[illegible]	[illegible].36
[illegible]	[illegible].1	[illegible]	[illegible]	[illegible].1	[illegible].29
[illegible]	[illegible].7	[illegible].41	[illegible]	[illegible].7	[illegible].79
[illegible]	[illegible].7	[illegible]	[illegible]	[illegible]	[illegible].89
[illegible]	[illegible].9	[illegible]	[illegible]	[illegible]	[illegible].30
[illegible]	[illegible].1	[illegible]	[illegible]	[illegible].3	[illegible].67
[illegible]	[illegible].3	[illegible]	[illegible]	[illegible]	[illegible].41
[illegible]	[illegible].1	[illegible]	[illegible]	[illegible].7	[illegible].31
[illegible]	167.8	[illegible]	[illegible]	[illegible]	[illegible].75
[illegible]	[illegible].9	[illegible]	[illegible]	[illegible]	[illegible].41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].9	[illegible].24
[illegible]	[illegible].5	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible].7	[illegible]	[illegible]	[illegible].8	[illegible].11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].2	[illegible].24
			[illegible]	[illegible].4	[illegible].77

Carbon dioxide. Temperature, 35.0°C

[illegible]	[illegible].8	[illegible].5[illegible]	[illegible]	134.[illegible]	[illegible].98
[illegible]	[illegible].9	[illegible].7[illegible]	[illegible]	[illegible].[illegible]	[illegible].9[illegible]
[illegible]	[illegible].4	[illegible]	[illegible]	189.[illegible]	[illegible].56
[illegible]	[illegible].9	[illegible].7[illegible]	[illegible]	136.7	[illegible].[illegible]1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].5	[illegible].59
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].48
[illegible]	[illegible].3	[illegible].3[illegible]	[illegible]	[illegible]	[illegible].93
[illegible]	[illegible].5	[illegible].77	[illegible]	[illegible]	[illegible].37
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].7	[illegible].[illegible]4
[illegible]	181.0	[illegible]	[illegible].5	[illegible]	[illegible].19
[illegible]	[illegible].7	[illegible]	[illegible]	[illegible].4	[illegible].13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].17
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].4	[illegible]
[illegible]	[illegible].4	[illegible]	[illegible]	[illegible]	11.14

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
Temperature = [illegible].7°C
Frequency = 74.1 kilocycles

Velocity	Pressure	Velocity	Pressure
meters/sec.	Atmospheres	meters/sec.	Atmospheres
344.1	58.48	-89	14.66
318.-	54.07	-	14.-
309.	51.-	-40	.93
3[illegible].6	5[illegible]	-[illegible].0	[illegible]
[illegible]	5[illegible].07	-[illegible].8	[illegible]
[illegible]	51.4-	[illegible]	+.1
[illegible]	5[illegible].0[illegible]	[illegible].1	[illegible]
[illegible]	51.17	[illegible].6	[illegible]
196.	5[illegible].26	[illegible].3	[illegible].7

Ethyl ether
Temperature = 18.7° C
Frequency = [illegible].1 kilocycles

[illegible].4	72.77	[illegible].1	[illegible].64
[illegible].6	[illegible].[illegible]	[illegible].4	[illegible]
[illegible].8	[illegible].38	[illegible].3	[illegible]
[illegible].[illegible]	[illegible].19	[illegible].7	[illegible]
[illegible].[illegible]	[illegible].18	[illegible].6	[illegible].81
[illegible].[illegible]	[illegible].7[illegible]	[illegible].6	[illegible].13
[illegible].[illegible]	[illegible].6[illegible]	[illegible].8	[illegible]
[illegible].[illegible]	[illegible].6[illegible]	[illegible].4	[illegible].71
[illegible].[illegible]	[illegible]	[illegible].5	[illegible]
[illegible].4	[illegible]	[illegible].8	[illegible]

Ethylene
Temperature = [illegible].0°C

Frequency	Velocity	Pressure	Frequency	Velocity	Pressure
Kilocycles	meters/sec	Atmospheres	Kilocycles	Meters/sec.	Atmospheres
[illegible].-	[illegible].9	[illegible].78	[illegible].0	[illegible].1	[illegible].84
[illegible].1	[illegible].3	[illegible].-	[illegible].0	[illegible].4	[illegible].69
[illegible].-	[illegible].1	[illegible].00	[illegible].1	[illegible].1	[illegible].58
[illegible].-	[illegible].[illegible]	[illegible].[illegible]	[illegible].0	[illegible].5	47.[illegible]
[illegible].-	[illegible].7	[illegible].[illegible]	[illegible].0	[illegible].4	44.[illegible]
[illegible].1	237.-	[illegible].6[illegible]	[illegible].0	[illegible].1	[illegible].[illegible]
[illegible].-	[illegible].4	64.[illegible]	[illegible].1	[illegible].1	41.34
[illegible].1	[illegible].7	[illegible].[illegible]	[illegible].-	[illegible].[illegible]	[illegible].[illegible]
[illegible].-	[illegible].[illegible]	[illegible].[illegible]	[illegible].0	[illegible].1	[illegible].19
[illegible]	[illegible].0	[illegible].[illegible]	[illegible].1	278.[illegible]	[illegible].7
[illegible].1	[illegible].1	[illegible].1	[illegible].1	[illegible].[illegible]	[illegible].74

The [illegible] and [illegible] critical [illegible],
[illegible] equilibrium curve of [illegible]
[illegible]
[illegible] continuation of the [illegible] curve,
predicted from the [illegible] by [Mackenzie] (8). The [illegible] becomes evident on inspection of the figure. Interest in the subject [illegible] by the recent work of [illegible] J. E. Mayer and his students (9), who have approached it from the point of view of statistical mechanics. The [illegible] two [isotherms] of the ratio of specific heats of CO_2 calculated from the values of sound velocity and the [illegible] (10). There are included [illegible] of the [illegible] conditions at the critical point and near it.

[illegible] fun, [illegible] for [illegible] reflection coefficient. These [illegible] fully [illegible] structure [illegible] reflecting [illegible] [illegible]ssed. However, [illegible] obtained [illegible] ficient [illegible] formation [illegible] for [illegible] table. The values given for the absorption and reflection coefficients are [illegible] correct to ± [illegible] percent.

α is defined by α = [illegible], [illegible] the [illegible] acoustic absorption coefficient given by $I_x = I_0 e^{-\alpha x}$. γ^* is the intensity coefficient of reflection.

Temperature	Pressure	Frequency	α	γ^*
[illegible] °C	54.[illegible]	[illegible].6 kc	.[illegible]2	.7[illegible]
3[illegible].[illegible]°C	53.7	[illegible]74.[illegible]	.[illegible]	.[illegible]
[illegible].[illegible]°C	43.[illegible]	[illegible]	.[illegible]4[illegible]	.[illegible]

[illegible] the [illegible] wishes to [illegible] J. C. [illegible], under whose direction [illegible], for [illegible] advice during the whole progress of the problem, to Professor A. H. [illegible] presentation of [illegible], [illegible] J. E. [illegible] for [illegible].

[illegible]

(1) ... H. ...ge, Thesis, Jo... ...pkl. Un...versit..., 19...4.

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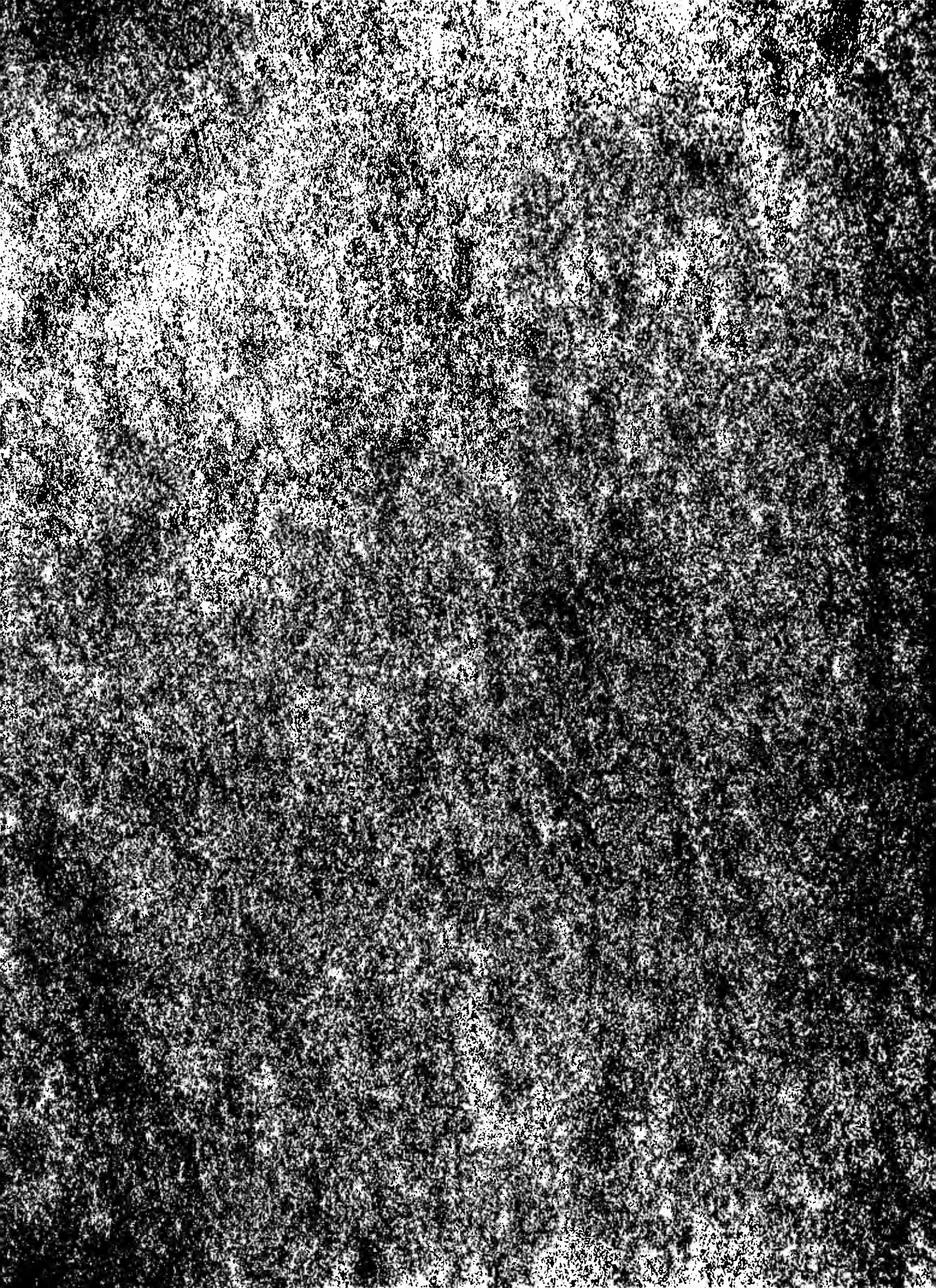
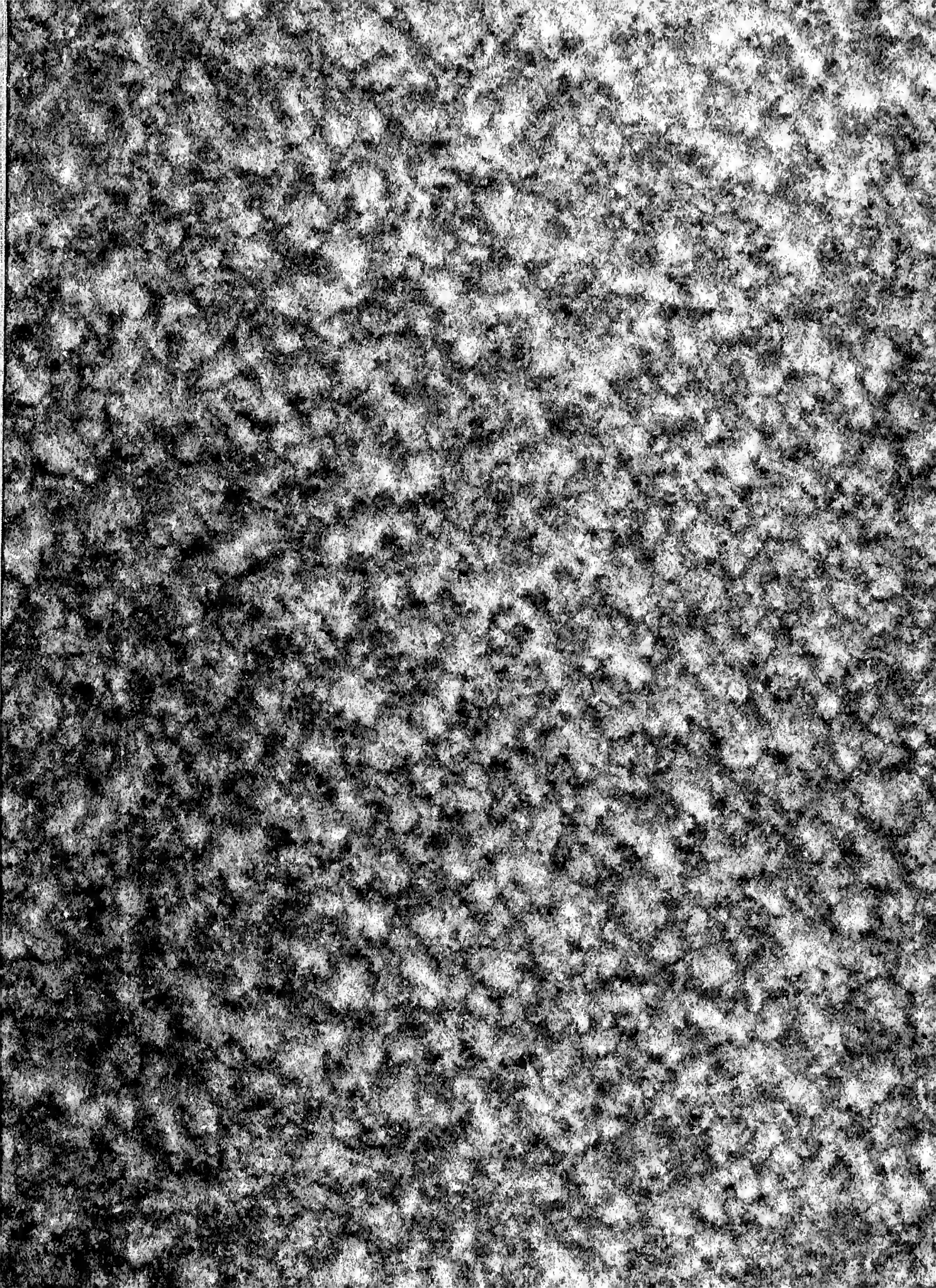
VITA

[illegible], born [illegible], [illegible], 1913. His [illegible] education was received in the public schools of [illegible]. In 1931 he entered the John Hopkins University, graduating two years later with the degree of A.B. [illegible]. He received the degree of John Hopkins in [illegible]. His [illegible] Professor [illegible], Ph.D., [illegible], [illegible], Dr. Leo, [illegible], Dr. Hugo [illegible]. In addition he has [illegible] Professor [illegible].